DOE/ORP-2002-03

Office of River Protection FY 2002 Integrated Technology Plan

February 1, 2002

Office of River Protection

Roadmapping for Science & Technology for the River Protection Project

DOE/ORP-2002-03

FY 2002 Integrated Technology Plan for the River Protection Project

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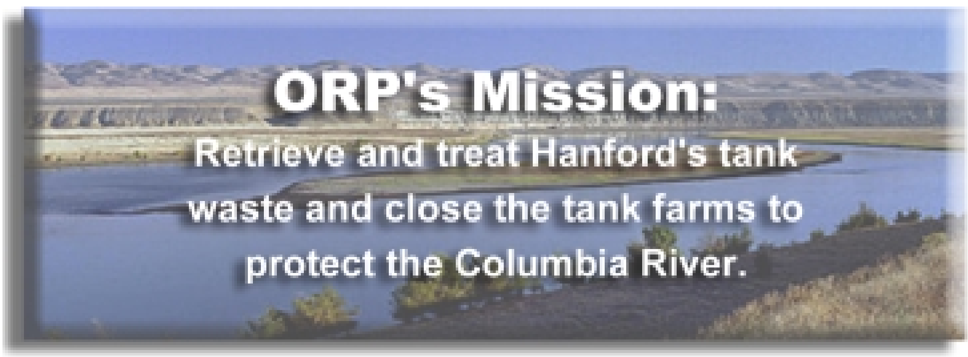
Executive Summary

Purpose and Scope

Approximately 200 million liters (53 million gallons) of highly radioactive wastes are stored in 177 large underground tanks at the Hanford Site in southeastern Washington State. That waste, from production of plutonium for the nation's nuclear defense program, has been accumulating since 1944. In 1998, Congress established the Office of River Protection (ORP) to manage the retrieval, treatment, and disposal of Hanford tank waste and to then close the tanks in compliance with the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement or TPA) between the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency, and the Washington State Department of Ecology (Ecology 1989). The tank waste must be managed to protect the Columbia River, the surrounding communities, and the economic future of the region. To implement its mission, the ORP manages the River Protection Project (RPP), formerly known as the Tank Waste Remediation System (TWRS).



The current ORP plan is divided into two phases, with 10% of the waste mass, containing 25% of the radioactivity, to be treated in Phase I (Initial Quantity) and the rest in the Balance of Mission (BOM), also commonly referred to as Phase II. Phased implementation was chosen so that waste treatment would start with robust, demonstrated technology while allowing flexibility to make changes later as new information and new technologies emerge.

Not all the challenges facing the RPP are technical ones, but new technologies and approaches need to be developed and deployed to help reduce RPP cost and schedule and to provide a technical baseline that is robust yet sufficiently flexible. The purpose of this Integrated Technology Plan (ITP) is to present a comprehensive discussion of the science and technology (S&T) advances needed to ensure successful completion of the ORP mission. To assist in this, a process called "roadmapping" is being used to complement existing S&T planning processes. Roadmapping provides a framework for integrating near-term baseline S&T issues with life-cycle technical challenges that have no readily available solutions or whose existing solutions either are too expensive or pose unacceptable risks.

Since the TPA was signed in 1989, several technology planning studies have been conducted and documented for treating the tank waste. In addition, a number of key technology planning activities have been ongoing. For example, S&T needs for Hanford's high-level waste (HLW) programs (tanks) are updated annually to provide details on many pressing scientific issues and technology needs (DOE 2002). Points at which such technologies can best be inserted (technology insertion points) are also tracked as project milestones. DOE-Headquarters S&T programs also address DOE complex-wide technical issues and the relationship of these issues to individual sites; the Multi-Year Program Plans prepared by the Tanks Focus Area (TFA 2000) and the HLW management technical issues summary in DOE's Research and Development Portfolio (DOE 2000) are examples of these. In the context of defining priority research issues, the National Research Council has also recently evaluated the HLW programs for the DOE Complex (NRC 2000). In 2001 the National Research Council also issued a report, *Research Needs for High-Level Waste Stored in Tanks and Bins at U.S. Department of Energy Sites, Environmental Management Science Program*, which provided recommendations to DOE's Environmental Management Science Program (EMSP). This revision of the ITP incorporates the EMSP-funded projects, resulting from the HLW directed call for proposals, that are Hanford tanks-related.

DOE-Richland Operations Office (RL) recently completed a strategic-level assessment of S&T challenges and opportunities for the Hanford Site (DOE 2001). As RL and ORP develop detailed S&T roadmaps, close collaboration will be maintained on common or interrelated technical challenges. In particular, ORP issues associated with tank farm closure significantly overlap cleanup challenges facing RL (in such areas as soils characterization, groundwater/vadose zone phenomenology, barrier development, remote subsurface access, removal and disposition of remote-handled equipment, and deactivation of highly contaminated facilities). This ITP represents the next step in using roadmapping methodology to enhance S&T planning and integration for ORP.

Key Functions

The RPP is composed of five major, interrelated technical functions that cover all technical activities necessary for achieving the RPP mission to complete the cleanup of Hanford's tank waste (ORP 2001):

- Store—Store waste safely until it can be retrieved for treatment and disposal.
- Retrieve—Retrieve waste from all tanks to the extent needed for closure and transfer it to the Waste Treatment Facility (WTP).
- Treat—Separate waste into two fractions, remove key radionuclides from the low-activity waste streams to be disposed on the Hanford Site and incorporate these radionuclides into the HLW stream, immobilize both waste streams, and package the waste in containers for storage and disposal.
- Dispose—Dispose of immobilized low-activity waste (ILAW) onsite in near-surface disposal facilities, store immobilized HLW (IHLW) onsite until it can be shipped to an offsite geologic repository, and dispose of secondary waste.
- Close—Close (or deactivate, decommission, and transfer) all RPP facilities and infrastructure and establish long-term monitoring capability for sites and facilities.

These functions can be further separated into subfunctions and constituent elements as needed to fully define the functional structure of the RPP. As an example, the Retrieve function is divided to separately address single-shell tank (SST) and double-shell tank (DST) retrieval because of the technical differences between

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these two subfunctions. Similarly, the Treat function is discussed in two parts to address the Initial Quantity treatment and BOM treatment separately because of the significant technical differences between these two phases of the work.

Life-Cycle Cleanup Costs and Schedule for the RPP

The cost to complete the RPP mission is substantial, so significant financial incentives exist to reduce it. One way to reduce cost is through S&T advancements. Total life-cycle costs to complete the RPP mission and disposition the Hanford tanks wastes are estimated to be ~$54 billion (in current year, i.e., escalated, dollars). Estimated RPP costs are shown in Figure ES.1, based on information from *River Protection Project FY2000 Multi-Year Work Plan Summary* (ORP 2000). Though the life-cycle estimate has not yet been formally allocated to the current technical functions, it can be generally observed that the opportunities for cost savings from improved understanding and technology are primarily in treating and retrieving the waste, although technological advances will likely play a significant role in each function.

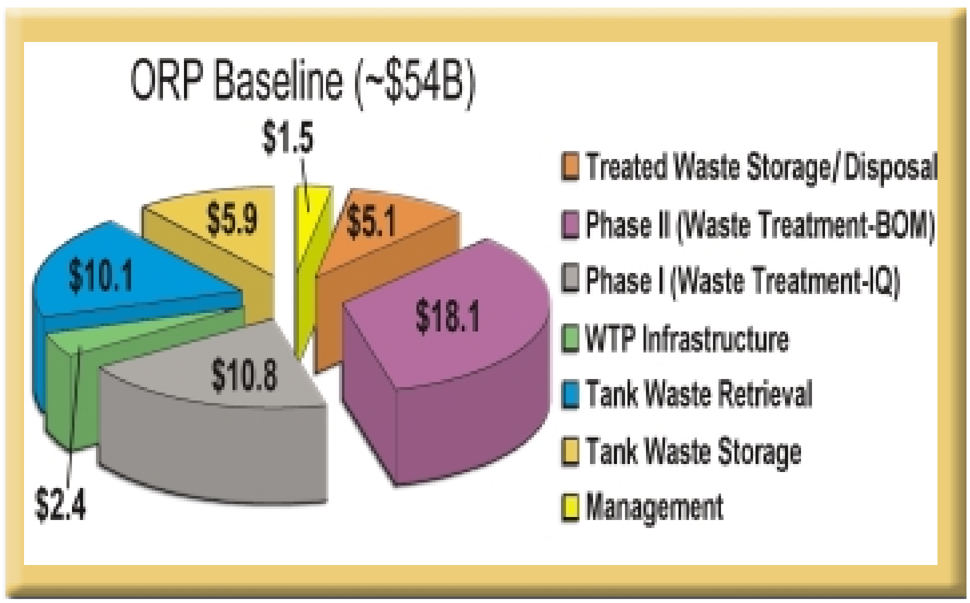

Figure ES.1. *Estimated RPP Total Cost Summary (dollars in billions)*

Figure ES.2 shows the key RPP timeline for completing the mission. While all of the identified dates are significant, the 2007 start of the WTP hot commissioning, the 2010 WTP Expansion Decision, and 2018 completion of SST retrieval are particularly important for S&T planning.

Neither the costs nor the schedule for the RPP includes long-term stewardship of the closed RPP facilities and infrastructure after the RPP mission is completed. Long-term stewardship refers to the costs of managing the closed facilities to protect public health and safety and the environment. These activities and costs are part of RL's overall Hanford Site responsibility and budget projections.

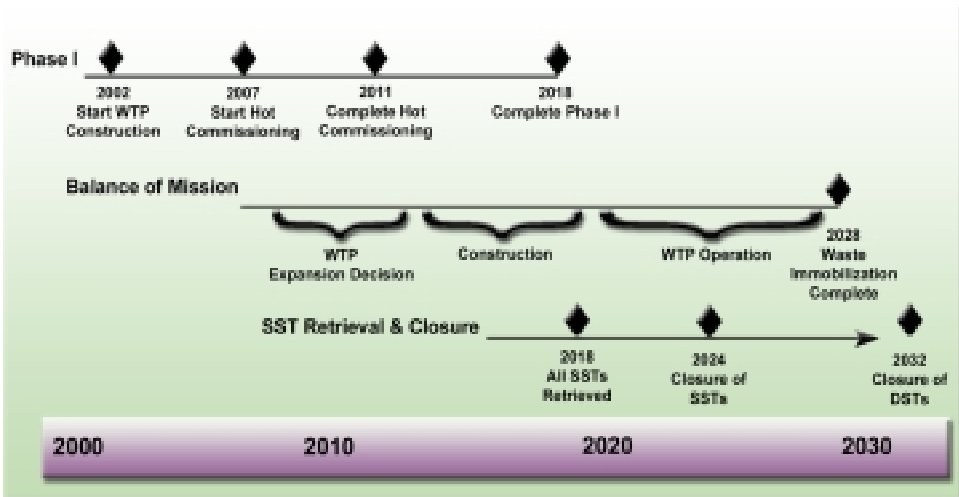

Figure ES.2*. RPP Summary Schedule*

Key Decisions/Performance Targets

A primary focus of this ITP is to identify key decisions/technical performance targets for the RPP. Each function for the RPP has a complete series of key decisions/performance targets. A number of these are particularly challenging and have been identified as *high-level* key decisions/performance targets. In many cases, these high-level key decisions/performance targets span multiple RPP functions and contractors, making integration even more challenging.

Table ES.1 summarizes the high-level key decisions/performance targets. They are not listed in any prioritized order; SST retrieval and BOM waste treatment begin the list because about half of the high-level key decisions/performance targets are associated with these topics. The key references citing these issues are also shown, although many additional documents are available that elaborate on the technical issues and background. As Table ES.1 shows, the high-level key decisions/performance targets have certain aspects in common:

- They require potentially large investments in either time or money.
- The confidence in achieving the desired outcome is uncertain.
- The feasibility of meeting the desired endpoint or end state either is uncertain or not-yet-defined breakthrough opportunities are possible to greatly reduce the schedule and cost for completing the mission.

RPP S&T Roadmap

Many of the high-level key decisions/performance targets are interrelated, and the point in time when technology solutions or information is needed varies. Key focuses of this ITP are to identify the critical times for these high-level key decisions/performance targets, to show their interrelationships, and to show examples of when technical developments need to begin so solutions and information are available in time to make a difference. Two figures, which compose a simplified version of the S&T roadmap for RPP, are presented here; a more detailed version of the S&T roadmap is presented in Figures 3.1 and 3.2.

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Table ES.1. High-Level Key Technical Decisions and Performance Targets for the RPP

High-Level Decision/ Performance Target	Challenge
1. Select SST Retrieval Technologies	The challenge is to develop SST retrieval technologies for sound and potentially leaky tanks, together with leak mitigation methods, that will meet retrieval standards for $25M per tank or less and allow a minimal leakage of waste. There is substantial urgency to retrieve and transfer SST waste into DSTs to reduce risk (Milestone 391, RPP EMSS).[a]
2. Determine and Optimize SST Retrieval Sequence	The retrieval sequence determines the pace at which the Site risk is reduced (retrieve high-risk tanks first), while balancing the cost of upgrading and constructing new infrastructure in the tank farms. The retrieval sequence must also coordinate with the waste feed and blending requirements for the WTP. Determining the retrieval sequence involves seeking the best balance of risk reduction, waste feed requirements, DST capacity, schedule, and costs for both retrieval and waste treatment (Milestones 689 to 694, RPP EMSS).[a]
3. Retrieve SST Waste by 2018	The TPA states that SST retrieval must be completed by 2018. The challenge is that the number of tanks to be retrieved per year to meet this schedule exceeds what can reasonably be accomplished. Retrieval will be further complicated by continued degradation of tanks and infrastructure during prolonged storage.
4. Define BOM Approach and Retrieval and WTP Processing Rates	This key decision requires understanding the performance of the initial WTP, the opportunity to include technology advancements to improve processing for the BOM, and the closure plan for the RPP (Milestone 571, RPP EMSS).[a] The WTP for initial treatment is intended to treat 10% of the waste volume and 25% of the activity. Deciding the processing rate will define the requirements for WTP expansion, DST space requirements, SST retrieval rates, and closure requirements (Milestone 580, RPP EMSS).[a]
5. Determine How to Expand WTP to Complete BOM	The RPP plan is to expand the initial WTP to increase the processing rates and modify the plant as needed to treat all the wastes. Providing all the technology to enable this expansion is the challenge (ORP 2001).
6. Determine HLW Melter for BOM	The planned expansion of the WTP provides an opportunity to insert improved HLW vitrification technology to increase the processing rate. The challenge is to develop and select a robust vitrification technology that greatly increases waste loading in HLW borosilicate glass (NRC 2000).
7. Determine Enhanced Cr Leaching for BOM	For waste that will be treated during the BOM, chromium (Cr) is currently identified as a key constituent limiting waste loading in HLW glass. While improved glass formulations and melter designs can help mitigate such limitations, improved pretreatment is also a promising alternative. The current challenge is to develop and select a robust, enhanced Cr leaching technology that greatly reduces chromium levels with relatively minor changes to the installed processing equipment in the WTP. Other limiting constituents may be identified as the work proceeds.

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***Table ES.1**. Continued*

8. Determine Lower-Cost ILAW Alternative	The challenge is to develop and obtain the acceptance of a process that greatly increases waste loading or lowers cost for ILAW (NRC 2000).
9. Determine Approaches and Technologies for High-Sulfate Waste	Sulfate is a significant system-wide issue with implications on ILAW waste volume, melter off-gas, treatment of recycle streams, and melter safety. Technology approaches are needed in either pretreatment or vitrification or both to handle sulfate (Harmon et al. 1999) and other constituents of concern.
10. Determine Approach for Cs and Sr Capsules	The challenge is to develop and qualify the chemical and mechanical processes required to convert the capsules into a waste feed that is compatible with the vitrification process. If the disposition plan is to vitrify the CsCl and SrF_2 salts, the effects of these components on the melter system, off-gas, and recycle streams need to be determined.
11. Manage Uncertainty and Variability in Waste Feed	Uncertainty in waste composition and variability in mixing and retrieval may result in batches of waste that do not meet feed specifications, particularly for minor components that substantially affect WTP processing. In addition, sampling of tank contents adds additional uncertainty and variability due to the complexity of the system being sampled.
12. Manage DST Waste to Allow SST Retrieval Without New DSTs	The ability to meet SST retrieval targets will be affected by limited DST space, and the challenge is to create enough usable DST space to enable continued waste retrieval from SSTs. This decision is tied to TPA Milestone M-45-00C (Ecology 1989) and evaluations of tank space options (Milestones 744 to 746 and 757 to 759, RPP EMSS).[a]
13. Maintain DST Integrity	The DSTs will exceed their initial design life before the BOM is completed. Managing very long-term corrosion behavior is a challenge (Washington Administrative Orders 00NWPKW-1250 and -1251).
14. Determine Tank Farm Closure Criteria	Defining closure criteria for SST farms will require improved understanding of tank residuals and subsurface contaminant transport. This decision is supported by updated closure plans every two years (Milestones 702 to 704, RPP EMSS).[a]
15. Determine ILAW Disposal Criteria	The RPP plan is to dispose of ILAW glass in a near-surface disposal facility at the Hanford Site. The disposal acceptance criteria depend strongly on the long-term (many thousands of years) performance of the ILAW glass and play critical roles in the design and performance of both the disposal facility and the ILAW vitrification facility. The challenge is to translate disposal acceptance criteria into engineering specifications so that the design of both the disposal and ILAW vitrification facilities can be completed, including determining what technologies will perform well enough to meet the relevant requirements.
16. Develop Approach for Failed Melter Disposal	Both the HLW and LAW melters are expected to be removed from service either as part of a planned replacement operation (referred to as a spent melter) or after melter failure. Failed HLW melters may require further processing prior to disposal. The extent of regulatory and physical activities required to allow disposal of a failed HLW melter at this time is unresolved. If the melters cannot be redesignated as mixed low-level waste (MLLW) and made acceptable for onsite disposal, the melter may need to be size-reduced or disassembled into discrete waste types (e.g., LLW, MLLW, transuranic, or HLW) and configurations suitable for packing and disposal. This is a particularly challenging decommissioning and decontamination (D&D) task.

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Table ES.1. *Continued*

17. Reduce Worker Health and Safety Risk	ORP is responsible for ensuring that work performed on the RPP is conducted efficiently and in a manner that protects workers, the public, and the environment. Considering the sheer volume of waste to be processed, together with the quantities of radioactive and other hazardous materials in the waste, there are considerable potential risks to workers. Technological innovations can significantly improve worker safety.
18. Close SST Farms by 2024	The TPA (Ecology 1989) states that the SST tank farms must be closed by 2024. Challenges for closure include measuring post-retrieval inventory, determining how to immobilize residual waste, and selecting and installing surface barriers and long-term monitoring equipment. Furthermore, the negotiation of closure criteria for the SST farms is linked to the outcome and timing of SST retrieval.

(a) ORP. March 21, 2001. *Draft RPP Expanded Management Summary Schedule.* Office of River Protection, Richland, Washington.

Figure ES.3 illustrates the interrelationships of the high-level key decisions/performance targets and their connections to the RPP major functions. As the figure shows, essentially all the high-level key decisions/performance targets link to more than one function. Because different contractors are responsible for the various functions or subfunctions, many of the high-level key decisions/performance targets affect multiple contractors. Figure ES.3 also shows the logic of how the high-level key decisions/performance targets are interrelated.

The most complex relationship occurs for the high-level key decision, *Define BOM Approach and Retrieval and WTP Processing Rates*. Roughly half of the high-level key decisions/performance targets are tied to this broad and critical decision. Figure ES.3 also includes examples of major S&T challenges and opportunities that, if solved, would address or resolve the high-level key decisions/performance targets. These S&T challenges and opportunities are grouped in the last column in Figure ES.3 to better illustrate the potential impacts to the RPP. The colors indicate the associated S&T challenges and opportunities. An important example of a grouping is *Enhance Throughput of the WTP to Avoid Building an Additional Facility*. As the figure shows, this grouping represents a number of S&T challenges and opportunities that target the high-level key decision, *Determine How to Expand WTP to Complete BOM*.

Figure ES.4 shows the schedule logic for these high-level key decisions/performance targets and how this logic relates to the overall top-level RPP schedule. Figure ES.4 also summarizes how the S&T challenges and opportunities from Figure ES.3 arrange by their S&T grouping for key decisions and performance targets. Selected top-level RPP schedule information is summarized at the top of the figure. Below the timeline, the key decisions and performance targets are arranged to show both the logic of their interrelationships and the time sequence when solutions and information are needed. The S&T challenges and opportunities are then summarized to show how technical solutions would support specific high-level key decisions/performance targets, again being organized by the groupings shown on Figure ES.3. While Figure ES.4 shows a rather complex relationship of activities, most of the activities are tied to the 2010 high-level key decision, *Define BOM Approach and Retrieval and WTP Processing Rates*. Accordingly, technology development for the BOM must be completed in time to affect this decision.

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Current S&T Investment Portfolio

The ORP S&T investment strategy includes integrating investments made directly by ORP with those conducted by other parts of the DOE Complex, including

- ORP contractors
- RL and its contractors
- DOE-Office of Environmental Management focus areas, particularly the Tanks Focus Area
- Cross-cutting programs
- EMSP
- Accelerated Site Technology Deployments.

This integration helps to maximize the benefit from DOE's investments and to minimize the potential for duplication of effort across the DOE Complex, as well as to leverage investments made for other purposes that may have aspects germane to the tank cleanup mission.

Gaps in S&T

The high-level key decisions/performance targets are critical areas in which technical solutions and information are needed. In some cases, substantial technical programs are creating the solutions and information, while in other cases little work has even been planned. Gaps are defined here as areas in which the planned S&T are not sufficient to accomplish these performance targets or make well-founded decisions. Through a preliminary analysis, five particular areas were identified in which planning appears incomplete and could be enhanced:

- waste treatment for the BOM
- SST retrieval rate to meet the 2018 TPA milestone for completing SST retrieval
- disposition of cesium/strontium capsules
- development of technologies and criteria for closing SST farms
- S&T enhancements for the balance of facility or critical support functions within the WTP equipment, such as remote handling and canister D&D.

These gaps largely occur in the current RPP baseline. Gaps can also be identified relating to broader DOE cleanup objectives, such as accelerated reduction of risks, quicker completion of cleanup missions such as the RPP, and more efficient approaches to achieving the required results. In a recent letter[a], the DOE identified a number of specific "Environmental Management Priorities" that are pertinent to the RPP, and additional gaps can be identified related to achieving these new priorities. Several initiatives are being undertaken by the RPP to identify opportunities that may arise by considering alternatives to the baseline approach for both near-term work and the BOM. The ITP is intended to provide information that can assist in these efforts. As these evaluations are completed and results made available, the S&T activities needed to enable the alternative approaches will be included in future revisions of this ITP.

(a) "Environmental Management Priorities," November 19, 2001. Memorandum for Director, Office of Management, Budget, and Evaluation, Chief Financial Officer, from Jessie Hill Roberson, Assistant Secretary of Energy for Environmental Management, US Department of Energy, Washington D.C.

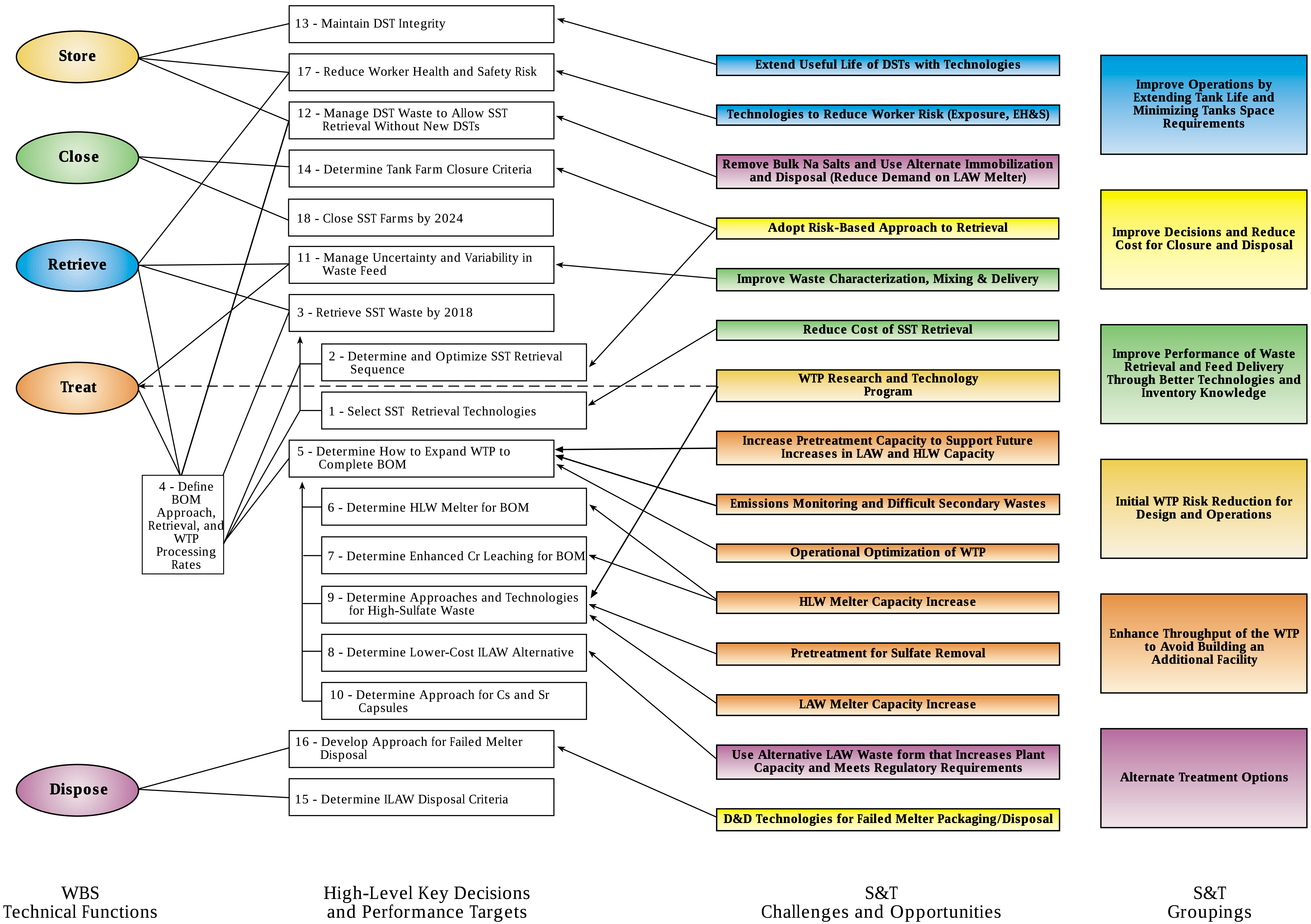

Figure ES.3. *Summary Logic for RPP High-Level Key Decisions/Performance Targets*

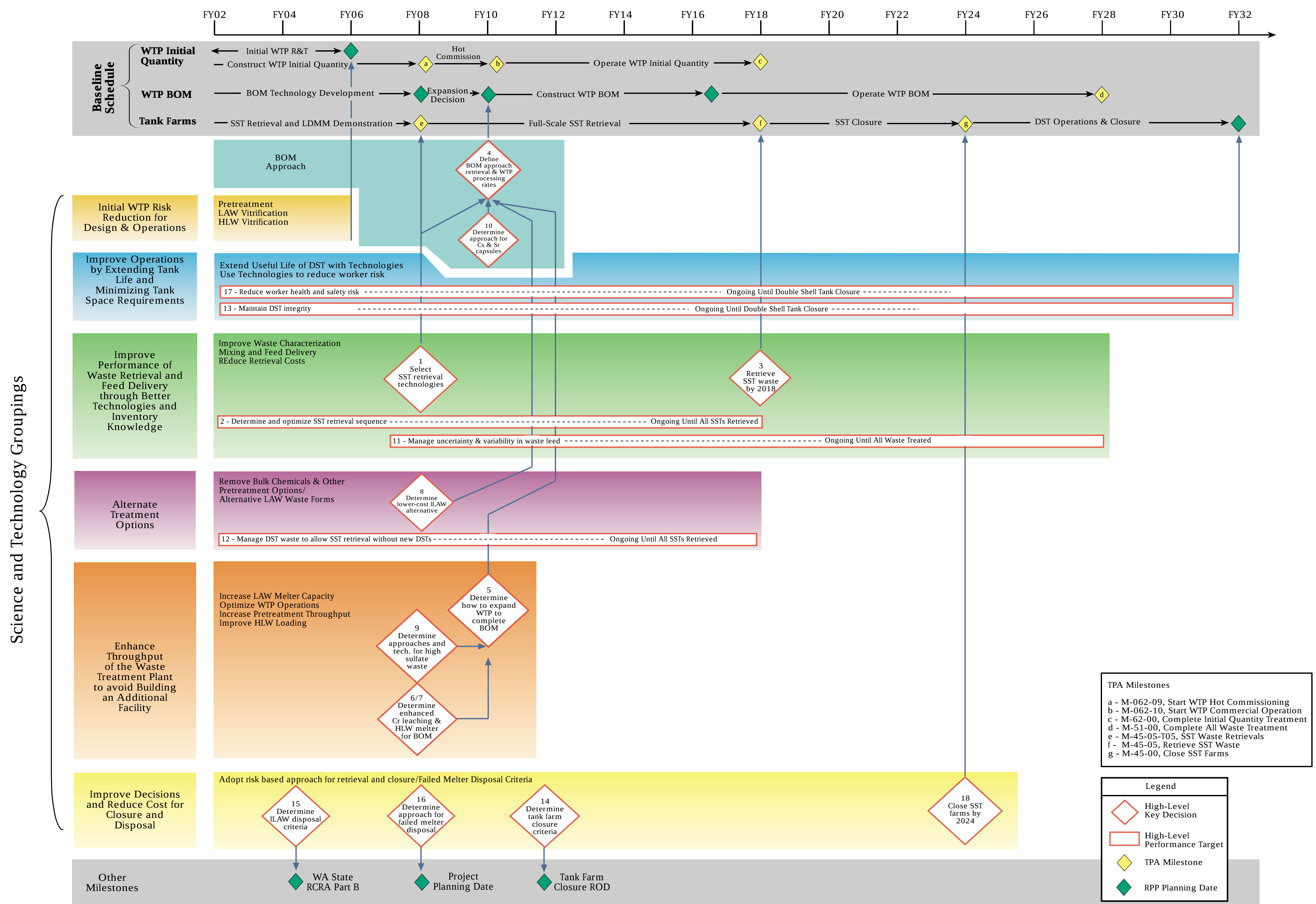

***Figure ES.4**. Summary Schedule Logic for RPP High-Level Key Decisions/Performance Targets and S&T Challenges and Opportunities*

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Acronyms & Initialisms

ASTDs	Accelerated Site Technology Deployments
ASTM	American Society for Testing and Materials
BOM	balance of mission
CHG	CH2M HILL Hanford Group
cm	centimeter
Cr	chromium
Cs	cesium
CST	crystalline silicotitanate
D&D	decommissioning and decontamination
DCRT	double–contained receiver tank
DOE	U.S. Department of Energy
DST	double-shell tank
Ecology	Washington State Department of Ecology
EDTA	ethylene diamine tetraacetic acid
EIS	environmental impact statement
EM	DOE-Environmental Management
EMSP	Environmental Management Science Program
EMSS	Expanded Management Summary Schedule
EN	electrochemical noise
EPA	U.S. Environmental Protection Agency
ES&H	environment, safety, and health
ESH&Q	environment, safety, health, and quality
ESP	Environmental Simulation Program
ETF	Effluent Treatment Facility
FY	fiscal year
GW/VZ	groundwater/vadose zone
HEDTA	hydroxy ethylene diamine tetraacetic acid
HEPA	high-efficiency particulate air
HLW	high-level waste
HTWOS	Hanford Tank Waste Operation Simulator
IDA	iminodiacetic acid
IHLW	immobilized high-level waste
ILAW	immobilized low-activity waste
IMUST	inactive miscellaneous storage tank
INEEL	Idaho National Engineering and Environmental Laboratory
IQ	Initial Quantity
ITP	Integrated Technology Plan

Acronyms & Initialisms

LAW	low-activity waste
LDMM	leak detection, monitoring, and mitigation
LLW	low-level waste
LOW	liquid observation well
MLLW	mixed low-level waste
MUST	miscellaneous underground storage tank
Na	sodium
NDE	nondestructive examination
NEPA	National Environmental Policy Act
NRC	National Research Council
NTA	nitrilotriacetic acid
ORNL	Oak Ridge National Laboratory
ORP	Office of River Protection
OSR	Office of Safety Regulation
OST	Office of Science and Technology
PA	Performance Assessment
PCB	polychlorinated biphenyl
PNNL	Pacific Northwest National Laboratory
ppm	parts per million
R&D	research and development
R&T	research and technology
RCRA	Resource Conservation and Recovery Act
RL	Richland Operations Office
ROD	Record of Decision
RPP	River Protection Project
S&T	science and technology
SAFT	Synthetic Aperture Focusing Technique
SBS	submerged bed scrubber
Sr	strontium
SRS	Savannah River Site
SST	single-shell tank
STCG	Site Technology Coordination Group
TBD	to be determined
TFA	Tanks Focus Area
TPA	Tri-Party Agreement
TRU	transuranic waste
TSCA	Toxic Substances Control Act
TWRS	Tank Waste Remediation System

VOC	volatile organic compound
WAC	Washington Administrative Code
WBS	work breakdown structure
WEF	Waste Encapsulation Facility
WESP	wet electrostatic precipitator
WRFs	Waste Receiving Facilities
WTP	Waste Treatment Plant

Acronyms & Initialisms

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